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Experimental work on the compressibility of eleven alkali halides, and its variation with pressure and temperature, has already been reported briefly by the author[1] in a paper dealing chiefly with theoretical deductions from the data. In the present paper, experimental details of the same investigation will be given. The measurements were carried out in Professor Bridgman's laboratory, using his recently developed method of measuring compressibility, and my sincerest thanks are due to him for his advice and interest. The samples were artificially prepared single crystals of the salts. The first section of the present paper deals with the preparation of the crystals; the second with the method of measurement; and the third with the results.

I. Preparation of Single Crystals.

For measuring compressibility, it is necessary to have sound samples, without cracks or flaws. The only satisfactory way to secure this result, with salts such as the alkali halides, seems to be to produce single crystals. Any aggregation of crystals, as in a metal, would lead to suspicion that there were flaws, which on account of the opacity of inhomogeneous material could not be detected. The first part of the research was therefore directed toward producing single crystals, large enough to make a sample out of one crystal. Methods of crystallizing from water solution were first tried, but without much success. Some of the salts are hygroscopic and cannot be crystallized from solution anyway, and in all of them there would be danger of mechanical inclusion of water. These facts, together with the poor success of my attempts to crystallize from solution, led me to the conviction that the most hopeful method lay in crystallizing from the molten salt at high temperature. Preliminary experiments showed that transparent crystals of considerable size could form very rapidly on solidification of the melt, although the normal state was a snow-like aggregate useless for the measurements. The following procedure

[1] Slater, Phys. Rev., 23, p. 488, 1924.

was finally worked out for making the crystals as large as possible, and extracting them without damage. Undoubtedly a more satisfactory process could be developed without great trouble; but the method used had the advantage of great simplicity of apparatus, and rapidity, and proved sufficient for supplying the necessary samples.

The salt was melted in a platinum crucible about an inch and a half in diameter, placed on an alundum stand about in the center of a vertical tubular electric furnace just large enough in diameter to accommodate it. The range of melting points for the salts used was roughly from 450° C. to 900° C. No material but platinum was found capable of resisting all the fused salts. The furnace had a rheostat for adjustment. It was open at the top, so that it was possible to look in, and see when the salt fused. After fusion, the furnace was adjusted so as to keep the salt somewhat above its melting point. The appearance of the salt gave a sufficient indication of the temperature, without any measuring device.

After fusing the salt and letting the liquid come to approximately constant temperature, a procedure was followed whose object was to cool a small area in the center of the top surface of the liquid, so that crystallization should start from there and spread through the crucible. By this means the crystallized material was in the form of a small number of crystals, rather than a large number as would be the case if there were many centers of crystallization. The method was to blow a sharp jet of air on the surface of the liquid, directed against a small platinum wire dipping below the surface. The air came from a compressed air tank, through a reducing valve, and was led into the furnace from the top through a small quartz tube, about an eighth of an inch outside diameter, passing down the axis of the furnace. The tube reached to within about a quarter of an inch from the surface. The platinum wire was held in place simply by sticking up inside the tube, being slightly bent so as to stay in place by friction, and was bent at its lower end into a small loop, which projected below the surface. The purpose of the wire was two fold: to furnish a point for the crystallization to start, and to provide a handle for lifting out the solid after it had formed. It would presumably have been better to suspend a seed crystal in the loop. This was tried a few times, with fair results, although it was difficult to prevent the seed from melting before the surrounding liquid was cool enough to start crystallizing; but in general it was not used, because only one melt was made of each salt, and there were no seeds to use. After blowing for a few minutes, crystallization would commence, in the form of a glass like

lump attached to the wire. This gradually would spread until the glassy material covered the surface. At the same time of course the crystalline material penetrated down. It hardly ever reached the bottom of the crucible, however; a stage would be reached when an aggregate of crystals would commence to form below the glassy material. This could be observed through the glassy salt, as a whitish appearance rather suddenly forming. The whole process occupied on the average perhaps half an hour. The careful adjustment of the air jet and of the temperature of the furnace, so as to crystallize fast enough to prevent re-melting of what had already crystallized, but not fast enough to start other flaky crystals on the surface, demanded considerable care.

When the crystalline material had formed, it was necessary to remove it from the crucible before allowing it to cool; otherwise it invariably cracked. This was easily accomplished by removing the quartz tube, lifting the salt and crucible bodily from the furnace by the platinum wire, and playing a flame on the outside of the crucible until the surface of the salt was melted and the crucible fell off. The crystalline material was then immediately replaced in the furnace, the current turned off, and the salt allowed to cool down with the furnace. By this method cracking was entirely avoided.

After cooling, the glassy mass was examined. It was found in general that the salts with large atomic weights, such as KI and RbI, had the largest mass of transparent crystals, while those of low atomic weights, as LiF and NaF, had the smallest; thus one melt of RbI was entirely converted into a single crystal, while on the other hand there was no crystal half an inch long from the melt of LiF. Generally there were four or five single crystals, grown together, making up the crystalline mass. These were separated by starting cuts with a jeweler's saw along the surface of separation, after which they broke apart. The directions of the planes of cleavage in an individual crystal were then found by chipping small pieces from the corners. Pieces were cut out, of approximately the size desired, surrounded by cleavage planes. By having all the faces cleavage planes, and by seeing that the material was perfectly clear, it was possible to be sure that a single crystal was being used.

The samples used for measurement were cylinders, three-sixteenths of an inch in diameter and about half an inch long. Blanks of square cross section were first made, as described above, one of the crystal axes being along the long dimension of the blank. These were then trimmed to approximately cylindrical form with a knife. The final

shaping was done in a bench lathe. It was found possible to turn the crystals without serious danger of breakage if they were held in the chuck surrounded with a cushion of paper saturated with oil, and if the tool was very sharp, used at high speed, and with a small cut. Finally the ends were stoned down on an oil stone, until they were of a mirror-like smoothness. Some of the salts were hygroscopic, and to prevent tarnishing by moisture they were kept moistened with oil while working, and the finished samples were kept under oil.

II. Measuring Apparatus.

The method of measurement was that described by Bridgman.[1] It is a measure of linear compressibility; but for cubic crystals, which are isotropic, the cubic compressibility can be found directly from the linear. A sample—in this case a cylinder of crystal—is placed under hydrostatic pressure. One end is held fixed, and the motion of the other end, as the crystal contracts, is magnified by a lever. The end of the lever carries a resistance wire, which slides over a contact fixed to the apparatus, so that the length of wire between the contact and another contact fixed to the wire varies linearly with the change in dimensions of the sample. The resistance of this piece of wire is then measured on a potentiometer, and, being proportional to the length, is a direct indication of the length of the sample. The only difference of any importance between the apparatus as it was used in this experiment and Bridgman's original apparatus came from the small samples used. The samples were held in a cylindrical steel jacket, its outside dimensions being the same as the size of the sample used by Bridgman, and the center just large enough to make an easy fit for the crystal. The crystal rested at each end against steel cylinders of the same diameter that it was, rather than against bearing points as in the case of the metal samples. One of these cylinders was made new for each sample, and of such length that it and the sample added up to a standard length. This made it possible to use samples of the most convenient length in each case. It was found necessary to polish on an oilstone the surfaces of crystal and steel cylinders which came in contact; for any variation in the length of the column of crystal and steel, resulting, for example, from irregularities in the steel digging into the soft crystal, would be communicated to the measuring apparatus as much as a real change in length of the crystal. At first the surfaces were merely finished in the lathe, and unexplained irregularities

[1] Bridgman, Proc. Am. Acad., 58, p. 165, 1923.

in the results were observed. These were traced to the rough ends, and when the practice of stoning was adopted, the irregularities disappeared.

The lever apparatus and potentiometer were all calibrated together, by removing the lever apparatus from the pressure cylinder, putting a micrometer screw in place of the sample, and observing the change of potentiometer reading as the screw was turned through a known distance. The magnifying power—the ratio of displacement of the potentiometer slider to the displacement of the end of the sample—was found to be 2292, with a probable error of about three-tenths of a percent. Any individual reading of the potentiometer was likely to be in error by about two millimeters of the slide wire, corresponding roughly to one micron in the length of the sample. This amount represented the variability of the apparatus.

The principal corrections arose from the change of specific resistance of the resistance wire with pressure, from the thermal expansion of the resistance wire, and from the contraction of the lever apparatus under pressure. The first affected the result because the change in resistance of the wire depended both on its length and specific resistance. The correction was made by using Bridgman's measurement of the change of resistance of nichrome with pressure. The thermal expansion was allowed for by using the known thermal expansion of nichrome. The third, the contraction of the apparatus under pressure, is simply another way of expressing the fact that the measurement is not one of absolute linear compressibility, but of compressibility relative to steel. These corrections were all small; except for LiF, the least compressible salt, the total correction to the compressibility was not more than two percent. Instead of making corrections on the individual experimental points, the constants of the experimental curves were determined as described in the next paragraph, and then corrections were made on the constants.

Measurements were made on each salt every thousand atmospheres up to twelve thousand atmospheres. The total displacement of the slider varied from ten centimeters in the least compressible salt to ninety in the most compressible. An individual reading, varying by about two millimeters, was thus likely to vary from two-tenths of a percent to two percent of the total displacement. The displacement was, as accurately as could be determined, a quadratic function of the pressure. Equations were fitted to these curves, and the two constants of the equations gave the initial compressibility and its initial change with pressure. The equations were found as follows: The

desired equation is of the form $d = ap + bp^2$, where d is the displacement, p the pressure, a and b constants. We can then write it $d/p = a + bp$. Thus if d/p is plotted against the pressure, the result should be a straight line. This method was used, the experimental points being plotted, the results in every case lying on a fairly satisfactory straight line, and the constants were found simply by drawing a straight line through the points and reading off its constants. The errors were magnified in this form of plotting, particularly at low pressures, but mental allowance was made for this in drawing a line. The equations of the second degree curves were also found by least squares, for guidance, although the results of this method were not blindly followed. After finding the constants a and b of the quadratic, the corrections were made on them, and the desired relations found from them. The compressibility was found from a alone, while the change with pressure depended principally on b. The analysis by which this was done, while slightly complicated, was perfectly straightforward, and need not be given.

Measurements were made at two temperatures, 30° C. and 75° C. The compressibility would be expected to vary with the temperature, but not to an observable extent the change of compressibility with pressure. Corresponding to this, the curves connecting d/p with p for the two temperatures should have the same slope but different intercepts. This was found in every case to be true, within the limit of error of the experiment. By combining the data for a given sample at different temperatures, and assuming that the slopes of both curves should be the same, it was possible to find the slope more accurately than from one curve alone. In some cases the constants obtained by least squares for the two temperatures did not agree, but those were found to be the cases where the individual points lay farthest from the curves, and in no case was it necessary to do violence to the data to assign the same slope to each.

The compressibility, determined from the slope of the curve of d against p, or the intercept of d/p against p, could be found in general to a percent or better. The significant errors were the error in determination of the constant for the curve, and the error in the constant of the apparatus, already stated as about three-tenths of a percent. The change in compressibility with pressure had an error perhaps five times as great, arising almost entirely from the inaccuracy in determining the constants from the data. This is found essentially from the difference in actual displacement at 12,000 atmospheres and the displacement which would occur if it varied linearly with the

pressure; and as this was in general about a fifth of the total displacement, and was subject to the same absolute errors, the relative error was greater in proportion. The change of compressibility with temperature was found from the compressibility as determined at two separate temperatures, and differing by perhaps three percent. The error is thus large, only the order of magnitude being given by the results. The errors were not quite as large as might be imagined, however; for the measurements at the two temperatures were made without taking the apparatus apart, and errors were likely to repeat; and only the difference in calibration at the two temperatures was used, determined from known constants, and not the calibration itself. Thus it is likely that the results are correct to twenty, or even ten, percent.

III. Detailed Data.

The measured quantities were defined as follows: If v is the volume of a certain quantity of substance, v_0 its volume under zero pressure, then the compressibility is defined as

$$\kappa = \frac{1}{v_0}\left(\frac{\partial v}{\partial p}\right)_T.$$

If κ_0 is the value of the compressibility under zero pressure, then the change of compressibility with pressure may be conveniently defined as

$$\psi_0 = \frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial p}\right)_T,$$

the derivative being taken at zero pressure. The two constants κ_0 and ψ_0, for a fixed temperature together with the change of compressibility with temperature, $1/\kappa_0(\partial\kappa/\partial T)p$, are the quantities measured. As stated above, it was at first not the practice to stone the ends of the crystal and steel cylinders, and this resulted in irregularities, but so far as was known in no outstanding errors. A considerable number of readings were made in this way, and they are given in the discussion to follow, although they are not weighted as much in determining the averages at the later readings. Measurements were made on eleven salts: LiF, LiCl, LiBr, NaCl, NaBr, KF, KCl, KBr, KI, RbBr, and RbI. Measurements had been previously made by Richards and Jones at low pressures on the chlorides, bromides, and iodides of sodium and potassium[1]; by Madelung and Fuchs[2] on NaCl

[1] Richards and Jones, J. Am. Chem. Soc., 31, p. 158, 1909.

[2] Madelung and Fuchs, Ann. d. Phys., 65, p. 289, 1921.

and KCl at low pressures; and by Adams, Williamson, and Johnston[1] at high pressures on NaCl. Since the work described in the present paper was performed, measurements have also been made by Richards and Saerens[2] on the lithium and rubidium salts at low pressures. These results are discussed under the individual salts. The detailed results follow:

LiF. This salt was from Eimer and Amend, stated by them to be pure. It is the most difficult salt of all to crystallize, and it was impossible to obtain a single crystal large enough, so that finally two crystals were fitted together. It was so hard and brittle that it could not be turned, but was shaped by hand. The bearing faces, however, were made as flat as with any other samples, and I do not think the sample as finally used was unsatisfactory. On account of the low compressibility, the relative errors were large. I presume the error in the κ_0 may be several percent, and in ψ_0 possibly fifteen percent, although the values of ψ_0 found from the curves at the two temperatures separately agreed within six percent. The absolute errors are probably no larger than for any other salt. The values found are

$$-\kappa_0 = 1.53 \times 10^{-12}/\text{dyne/cm}^2, \quad -\psi_0 = 11.7 \times 10^{-12}/\text{dyne/cm}^2,$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 1.9 \times 10^{-4}/\text{degree}.$$

Herafter all compressibilities and changes of compressibility with pressure will be expressed in reciprocal dynes per square centimeter, and this unit is to be understood when it is not stated explicitly. Similarly changes of compressibility with temperature are in reciprocal degrees centigrade.

LiCl. This was from stock. It was crystallized without serious difficulty, although two trials were necessary, and a fairly good sample was obtained, perfect except for a small slightly cloudy place in one corner. It was kept covered with oil, and showed only a slight tarnish on the surface; its hygroscopic character did not appear to interfere with the reliability of the results. Measurements were made with the apparatus before its improvements; they were entirely satisfactory, and gave

$$-\kappa_0 = 3.41 \times 10^{-12}, \quad -\psi_0 = 19.8 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 6.9 \times 10^{-4}.$$

[1] Adams, Williamson, and Johnston, J. Am. Chem. Soc., 41, p. 12, 1919.

[2] Richards and Saerens, J. Am. Chem. Soc., 46, p. 934, 1924.

Richards and Saerens' results for the compressibility was 3.7×10^{-12}. Unfortunately, between the time of measurement and the time when the apparatus was improved, a drop of water found its way to the crystal, and it disintegrated. Since there was no more crystallized material, and since the readings had appeared to be perfectly good, measurements were not repeated after the improvement.

LiBr. Not much difficulty was found in crystallizing this salt, which was also from Eimer and Amend. Measurements were made only after the improvement of the apparatus; the runs were good, with small variations, and the runs at the two temperatures gave values of ψ_0 differing by about four percent. The final values are

$$-\kappa_0 = 4.31 \times 10^{-12}, \quad -\psi_0 = 24.5 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 8.4 \times 10^{-4}.$$

Richards and Saerens find 5.0×10^{-12}.

NaCl. Natural rock salt crystals were used. Runs with the apparatus before improvement, were made on two samples; the first, the earliest run made with the apparatus, gave

$$-\kappa_0 = 4.38 \times 10^{-12}, \quad -\psi_0 = 22.5 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 9.6 \times 10^{-4}.$$

A second gave

$$-\kappa_0 = 4.22 \times 10^{-12}, \quad -\psi_0 = 20.4 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 2.6 \times 10^{-4}.$$

The difference between the compressibilities is no more than was often found before the practice of stoning the faces was adopted. The variation in change of compressibility with temperature is the largest that was found for any substance. The mean of these is

$$-\kappa_0 = 4.30 \times 10^{-12}, \quad -\psi_0 = 21.4 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 6.1 \times 10^{-4}.$$

After the improvement of the apparatus, a run was made on the first of the two samples above; it gave

$$-\kappa_0 = 4.20 \times 10^{-12}, \quad -\psi_0 = 21.9 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 7.5 \times 10^{-4},$$

in satisfactory agreement with the mean of the previous values, considering their large error. As final, I take the values of κ_0 and ψ_0 from this sample, and for $1/\kappa_0(\partial\kappa/\partial T)_p$ the value 6.8×10^{-4}, giving some weight to the previous runs.

Several people have measured this salt before. Their results are for 20°; reducing this value to that temperature gives $-\kappa_0 = 4.17 \times 10^{-12}$. Richards, making a correction for an old value of the compressibility of steel which he used, found 4.30×10^{-12}; Adams, Williamson, and Johnston's value was 4.12×10^{-12}; and Madelung and Fuchs's, 4.14×10^{-12}. Adams, Williamson, and Johnston also determined ψ_0; their value, corrected for Bridgman's redetermination for steel, was 15×10^{-12}. It is thus seen that the value of compressibility found agrees well with the mean of previous observations, and the change of compressibility with pressure agrees as well with the one previous value as could be expected from the larger error in the method then used.

NaBr. This salt was from stock. Quite a little trouble was found in making the crystal, but the sample was perfectly satisfactory. A run was made before improving the apparatus, giving

$$-\kappa_0 = 5.08 \times 10^{-12}, \quad -\psi_0 = 23.1 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 8.4 \times 10^{-4}.$$

After improvement, a run was made which was somewhat poorer than usual, with variations larger than the average, and values of ψ_0 determined at the two temperatures differing by about twenty percent. The constants are

$$-\kappa_0 = 5.08 \times 10^{-12}, \quad -\psi_0 = 25.5 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 7.1 \times 10^{-4},$$

in good agreement with the previous results. As final values, I take the compressibility and change with pressure from this run, and 7.5×10^{-4} for the temperature coefficient. Richards's corrected value is 5.27×10^{-12}, in fair agreement with this result.

KF. This salt, again a difficult one, was from Eimer and Amend, and stated to have very small impurities. Its melting point is high, and this made the process of crystallization rather difficult. A good sample was obtained, however. A rough preliminary run, made to test the pressure apparatus, gave a result agreeing closely with that of the final run. The relative variations were naturally large. The change of compressibility with pressure at the two temperatures agreed exactly. The final values are

$$-\kappa_0 = 3.31 \times 10^{-12}, \quad -\psi_0 = 20.1 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 1.2 \times 10^{-4}.$$

KCl. The salt was from stock, and was originally from Merck. It was easily crystallized, and one melt yielded a large amount of usable material. More readings were made on this substance than on any other; it was used in testing the apparatus before the improvement, to try to locate the source of error. Readings were made on four samples, and in some cases several runs were made on a single sample. The results obtained before the improvement of the apparatus were

$-\kappa_0$	$-\psi_0$	$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p$
5.58×10^{-12}	24.4×10^{-12}	
5.49	23.3	
5.57	24.4	5.1×10^{-4}
5.75	28.8	
5.74	27.7	
5.68	27.1	
5.63	26.1	
5.60	25.3	4.5
5.79	31.1	

The list gives a good idea of the range of variation of the constants before the improvement of the apparatus. The average of these results is

$$-\kappa_0 = 5.65 \times 10^{-12}, \quad -\psi_0 = 26.4 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 4.8 \times 10^{-4}.$$

After the improvement, readings were made on two samples, which previously had given results far apart. The values are

$$-\kappa_0 = 5.62 \times 10^{-12}, \quad -\psi_0 = 26.2 \times 10^{-12},$$

and

$$5.63 \qquad\qquad 26.7.$$

These are seen to be in good agreement with each other, and with the mean of the previous results. No readings were made on the temperature coefficient after improvement. The final results are taken to be

$$-\kappa_0 = 5.63 \times 10^{-12}, \quad -\psi_0 = 26.5 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 4.8 \times 10^{-4}.$$

The compressibility is, I believe, correct to three or four tenths of a percent, and the change of compressibility with pressure to less than two percent. It is thus known more accurately than for any other salt. Richards's result is 5.22×10^{-12}, and seems to be plainly too low. The value of Madelung and Fuchs is 5.62×10^{-12}, in very good agreement with the figure above.

KBr. This was the first salt crystallized; good samples were obtained. Before the improvement of the apparatus, runs on two separate samples gave

$$-\kappa_0 = 6.70 \times 10^{-12}, \quad -\psi_0 = 32.0 \times 10^{-12},$$

$$6.58 \times 10^{-12} \qquad\qquad 29.2 \times 10^{-12}$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 9.8 \times 10^{-4}$$

$$4.3 \times 10^{-4}$$

After improvement, a run was made, with somewhat larger variation than ordinarily, the separate curves giving about ten percent difference between the values of ψ_0 at the two temperatures; the values are

$$-\kappa_0 = 6.75 \times 10^{-12}, \quad -\psi_0 = 31.9 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 5.5 \times 10^{-4}.$$

As final, I take

$$-\kappa_0 = 6.70 \times 10^{-12}, \quad -\psi_0 = 31.8 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 6.0 \times 10^{-4}.$$

Richards's value for the compressibility is 6.42×10^{-12}, again somewhat lower.

KI. This salt was obtained from stock, and was extremely easy to crystallize. There were no indications of decomposition. Before improvement, two runs were made which gave very discordant values, and values which did not seem to be anywhere near what they should be. It was these runs that led me to investigate the errors in the apparatus. After improvement, two separate runs were made on the same sample, giving

$$-\kappa_0 = 8.53 \times 10^{-12}, \quad -\psi_0 = 38.4 \times 10^{-12},$$

and

$$8.50 \qquad 39.7.$$

These runs were the first ones made after the improvement. Another run was made, the last run on any sample, quite a while after this. It gave

$$-\kappa_0 = 8.59 \times 10^{-12}, \quad -\psi_0 = 39.1 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 6.0 \times 10^{-4}.$$

The agreement between the runs, with a considerable time interval between them, is very satisfactory. As final, I take

$$-\kappa_0 = 8.54 \times 10^{-12}, \quad -\psi_0 = 39.1 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 6.0 \times 10^{-4}.$$

Professor Richards's value is 8.8×10^{-12}.

RbBr. This salt was obtained from Eimer and Amend, and was stated to be pure. It was crystallized fairly satisfactorily; no single crystal large enough to make a sample could be found, however, and it was necessary to make one from a blank with a joint between crystals in it. On account of the softness it was possible to turn it without breaking, and the resulting sample seemed to be satisfactory. It was found that this salt has a polymorphic transition under pressure. The band of indifference about the transition point is about two thousand atmospheres wide, so that no accurate measurement of the transition pressure was possible. Neither could an accurate measurement of the change of volume be found, since when a solid suffers a transition under pressure, its shape is likely to be distorted; as a matter of fact during the last run made on the sample, its diameter increased about

six thousandths of an inch, making it stick in the sleeve, and of course disturbing the readings. The transition point was approximately five thousand atmospheres, and varied very little with temperature; if anything, it was displaced slightly to higher pressure at high temperature. The change of volume was rather large, and appeared to be about six percent. The first time runs were made on the sample, before it was known that it had a transition, only three points were obtained before the change occurred; the change of volume was so large that the lever came to the end of its motion. When the pressure was released, the zero point returned a little beyond its original position—something that never occurred for any salt which had no transition. This was then repeated at 75°. The next day the sample was taken out, found to be opaque but not much distorted, and was put in with a larger steel base, so as to have, more chance for motion, and the run repeated. This time, the change of length on transition was not more than half what it had been the day before; the value of the initial compressibility was about the same, but the change of compressibility with pressure was about thirty or forty percent smaller. The smaller value is nearer what would be expected to be correct, and for this reason I adopt it. (This is the only case where I have discriminated between runs on account of what I thought the answer ought to be). On this second run, a good value for the compressibility of the high pressure modification was found. At the end of this run, the change of length coming down was greater than going up, about the same as the day before; but after the sample was taken out, it was found to have increased decidedly in diameter. The results on this substance, of course, had to be obtained in a range of pressure less than half the ordinary one in extent. For this reason, and also because undoubtedly the transition introduced mechanical imperfections into the sample, the results may be expected to have larger errors than the previous ones. For the low pressure phase, I find

$$-\kappa_0 = 7.94 \times 10^{-12}, \quad -\psi_0 = 35 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 1.7 \times 10^{-4}.$$

Richards and Saerens found 8.2×10^{-12} for $-\kappa_0$. For the high pressure phase, the results being extrapolated so as to refer to a normal state at zero pressure, the constants are

$$-\kappa_0 = 5.7 \times 10^{-12}, \quad -\psi_0 = 16 \times 10^{-12},$$

much smaller than for the other. The high pressure calculations rest on the assumption that the high pressure modification is cubic. It is to be presumed that this second phase is a body centered cubic modification, of the same crystal structure as RbF, and as the caesium salts with the exception of the fluoride. This is a structure of smaller volume, and would be expected to be formed at high pressure.

RbI. This was also from Eimer and Amend, and was the easiest salt of all to crystallize. It likewise has a polymorphic transition at apparently very nearly the same place as for RbBr, and of the same nature. A number of points were taken going up before the transition had taken place, and the sample was made larger than usual, so as to get a good value of the compressibility of the low pressure phase. The curve was fairly good, and the results should be fairly reliable. The constants are

$$-\kappa_0 = 9.62 \times 10^{-12}, \quad -\psi_0 = 43.6 \times 10^{-12}.$$

This sample was so long that the transition produced a change of length beyond the capacity of the apparatus. A second sample, about half the length, was made, and readings made at both temperatures before the transition occurred, keeping the pressure below the transition pressure. This gave

$$-\kappa_0 = 9.54 \times 10^{-12}, \quad -\psi_0 = 42.5 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 6.8 \times 10^{-4},$$

in satisfactory agreement with the other sample. As final values for the low pressure phase, I take

$$-\kappa_0 = 9.58 \times 10^{-12}, \quad -\psi_0 = 43.0 \times 10^{-12},$$

$$\frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p = 6.8 \times 10^{-4}.$$

The value of Richards and Saerens is 9.3×10^{-12}. The pressure was then increased beyond the transition, and measurements were made on the high pressure phase. The change of volume was apparently about eleven percent at the transition. The constants of the high pressure phase, extrapolated to refer to an initial state at zero pressure, were

$$-\kappa_0 = 9.6 \times 10^{-12}, \quad -\psi_0 = 58 \times 10^{-12}.$$

The fact that here the compressibility and its change with pressure

come out as large for the high pressure phase as for the low pressure one, while with RbBr they were much smaller for the high pressure phase, seems to throw doubt on the measurements for the high pressure phase for both salts. The constants could be determined with fair accuracy from the curves; but the sample may well have been distorted during the transition, and may not have given the true value of the compressibility. The method is not well suited for studying polymorphic transitions.

A table will now be given containing the values of these constants. As before, the compressibilities and change of compressibility with pressure are in reciprocal dynes per square centimeter, and the change of compressibility with temperature is in reciprocal degrees centigrade.

Salt	$-10^{12}\kappa_0$	$-10^{12}\psi_0$	$10^4 \frac{1}{\kappa_0}\left(\frac{\partial \kappa}{\partial T}\right)_p$
LiF	1.53	11.7	1.9
LiCl	3.41	19.8	6.9
LiBr	4.31	24.5	8.4
NaCl	4.20	21.9	6.8
NaBr	5.08	25.5	7.5
KF	3.31	20.1	1.2
KCl	5.63	26.5	4.8
KBr	6.70	31.8	6.0
KI	8.54	39.1	6.0
RbBr	7.94	35	1.7
RbI	9.58	43.0	6.8

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